Claims

[c1] 1. A multiple-input multiple-output (MIMO) radio transceiver on a single semiconductor integrated circuit, comprising:

a. a receiver comprising at least first and second receiver circuits each to process a signal from a corresponding one of first and second antennas, the first receiver circuit downconverts a first receive signal detected by the first antenna to produce a first baseband signal, the second receiver circuit downconverts a second receive signal detected by the second antenna to produce a second baseband signal; and

b. a transmitter comprising at least first and second transmitter circuits, the first transmitter circuit upconverts a first baseband transmit signal to generate a first radio frequency signal that is coupled to the first antenna for transmission, the second transmitter circuit upconverts a second baseband transmit signal to generate a second radio frequency signal that is coupled to the second antenna for transmission.

[c2] 2. The radio transceiver of claim 1, and further comprising a local oscillator coupled to the receiver and to the

transmitter, the local oscillator supplying a local oscillator signal to each of the first and second receiver circuits used for downconverting the first and second receive signals, respectively, and supplying a local oscillator signal to each of the first and second transmitter circuits used for upconverting the first and second baseband transmit signals, respectively, to a desired frequency for the first and second radio frequency signals, respectively.

[c3] 3. The radio transceiver of claim 2, wherein the first receiver circuit and the second receiver circuit process the first and second receive signals substantially simultaneously to allow for combining of signals resulting from processing by the first and second receiver circuits.

[c4] 4. The radio transceiver of claim 2, wherein the first transmitter circuit and the second transmitter circuit process the first and second baseband transmit signals for transmission of the corresponding first and second radio frequency signals substantially simultaneously.

[c5] 5. The radio transceiver of claim 1, and further comprising a frequency synthesizer that produces a local oscillator signal that is coupled to each of the first and second receiver circuits to be mixed with the first and second receive signals, respectively, wherein the local oscillator

signal may be at any frequency within one or more discrete radio frequency bands to receive the first and second receive signals at a common frequency, and wherein the frequency synthesizer generates a local oscillator signal that is coupled to the first and second transmitters to upmix the first and second baseband transmit signals, respectively, for transmission of the corresponding first and second radio frequency signals at a common frequency within the one or more radio frequency bands.

[c6] 6. The radio transceiver of claim 1, wherein the first and second receiver circuits comprise a single stage mixing process to downconvert the first and second receive signals directly to baseband.

[c7] 7. The radio transceiver of claim 1, wherein the first and second receiver circuits comprise a two stage mixing process to downconvert the first and second receive signals to first and second intermediate frequency signals at a common intermediate frequency, and then to first and second baseband signals.

[c8] 8. The radio transceiver of claim 7, and further comprising a frequency synthesizer that supplies a radio frequency local oscillator signal and an intermediate frequency local oscillator signal to the first and second re-

ceiver circuits, wherein the intermediate frequency local oscillator signal is derived from the radio frequency local oscillator signal by a division ratio.

[c9] 9. The radio transceiver of claim 1, and further comprising a first power amplifier in the first transmitter circuit that amplifies the first radio frequency signal and a second power amplifier in the second transmitter circuit that amplifies the second radio frequency signal.

[c10] 10. The radio transceiver of claim 1, wherein each of the first and second receiver circuits comprises a radio frequency mixer that down-mixes the first and second receive signals, respectively, to an intermediate frequency signal, and a pair of quad mixers that down-mix the intermediate frequency signal to in-phase and quadrature baseband signals.

[c11] 11. The radio transceiver of claim 1, and further comprising first and second lowpass filters, the first lowpass filter having inputs and an output and being shared by the first transmitter circuit and first receiver circuit, to filter either the first baseband transmit signal that is output to the first transmitter circuit or to filter the first baseband signal produced by the first receiver circuit, and the second lowpass filter having inputs and an output and being shared by the second transmitter circuit

and second receiver circuit to filter either the second baseband transmit signal that is output to the second transmitter circuit or to filter the second baseband signal produced by the second receiver circuit, and further comprising a first switch having an output coupled to an input of the first lowpass filter and that couples to the input of the first lowpass filter either the first baseband transmit signal or the first baseband signal, and a second switch having an output coupled to an input of the second lowpass filter and that couples to the input of the second lowpass filter either the second baseband transmit signal or the second baseband signal.

[c12] 12. The radio transceiver of claim 1, wherein the first receiver circuit comprises first and second radio frequency mixers, wherein the first radio frequency mixer down-mixes the first receive signal to an intermediate frequency signal when the first receive signal is in a first radio frequency band and the second radio frequency mixer down-mixes the first receive signal to an intermediate frequency signal when the first receive signal is in a second radio frequency band, and wherein the second receiver circuit comprises first and second radio frequency mixers, wherein the first radio frequency mixer down-mixes the second receive signal to an intermediate frequency signal when the second receive signal is in a

first radio frequency band and the second radio frequency mixer down-mixes the second receive signal to an intermediate frequency signal when the second receive signal is in the second radio frequency band.

[c13] 13. The radio transceiver of claim 12, wherein the first receiver circuit further comprises a pair of quad mixers coupled to the output of the first and second radio frequency mixers to further down-mix the intermediate frequency signal to the first in-phase and quadrature baseband signals representative of the first receive signal, and the second receiver circuit further comprises a pair of quad mixers coupled to the output of the first and second radio frequency mixers to further down-mix the intermediate frequency signal to the second in-phase and quadrature baseband signals representative of the second receive signal.

[c14] 14. In combination, the radio transceiver of claim 1, and a radio front-end section comprising:
a. a first transmit/receive switch to be coupled to the first antenna and a second transmit/receive switch to be coupled to the second antenna, wherein the first and second transmit/receive switches each comprise an antenna terminal to be coupled to the first and second antenna, respectively, a receive output terminal and a transmit input terminal, the transmit input terminals of

the first and second transmit/receive switches being coupled to the output of the first and second transmitter circuits, respectively, wherein the first and second transmit/receive switches are responsive to a control signal to select one of the two output terminals; and

b. first and second bandpass filters, the first bandpass filter coupled to the receive output terminal of the first transmit/receive switch and the second bandpass filter coupled to the receive output terminal of the second transmit/receive switch, the first and second bandpass filters filter the signals detected by the first and second antennas, respectively, to produce the first and second receive signals.

[c15] 15. The combination of claim 14, wherein the first and second bandpass filters are dedicated to filtering signals in a first radio frequency band, and further comprising:

a. third and fourth bandpass filters dedicated to filtering signals in a second radio frequency band;

b. first and second band select switches, the first and second band selection switches having an input terminal coupled to the receive output terminals of the first and second transmit/receive switches, respectively, and each having a first output terminal coupled to the first and second bandpass filters, respectively, and a second output terminal coupled to the third and fourth bandpass

filters, respectively.

[c16] 16. The combination of claim 15, wherein the radio front-end section further comprises third and fourth band select switches, each having first and second input terminals, and an output terminal, the output terminal of the third and fourth band select switches being coupled to the transmit input terminals of the first and second transmit/receive switches.

[c17] 17. The combination of claim 16, wherein the radio front-end section further comprises first and second lowpass filters dedicated to filtering signals to be transmitted in the first radio frequency band, the outputs of the first and second lowpass filters being connected to the first input terminals of the third and fourth band select switches, respectively, and third and fourth lowpass filters dedicated to filtering signals to be transmitted in the second radio frequency band, the outputs of the third and fourth lowpass filters being connected to the second input terminals of the third and fourth band select switches.

[c18] 18. In combination, the radio transceiver of claim 1, and a radio front-end section, wherein the radio front end section comprises a first diplexer to be coupled to the first antenna and a second diplexer to be coupled to the

second antenna, wherein the first and second diplexers each have first and second branches onto which signals from first and second radio frequency bands, respectively, are coupled for transmission via the first and second antennas, respectively, or are coupled when received by the first and second antennas, respectively.

[c19] 19. The combination of claim 18, wherein for each diplexer, the radio front-end section further comprises a bandpass filter coupled in the first branch to filter signals received in the first frequency band and a bandpass filter coupled in the second branch to filter signals received in the second frequency band.

[c20] 20. The combination of claim 19, wherein the radio-front end section further comprises a transmit/receive switch coupled to the bandpass filter in each of the first and second branches for each diplexer, wherein the transmit/receive switch selects either a signal to be transmitted through an antenna coupled to the associated diplexer, or a signal detected by an antenna coupled to the associated diplexer which is coupled to the bandpass filter for that branch.

[c21] 21. The combination of claim 19, wherein the radio transceiver further comprises a transmit/receive switch coupled to the bandpass filter in each of the first and

second branches for each diplexer, wherein the transmit/receive switch selects either a signal to be transmitted through an antenna coupled to the associated diplexer, or a signal detected by an antenna coupled to the associated diplexer which is coupled to the bandpass filter for that branch.

[c22] 22. The combination of claim 21, wherein the radio front-end section further comprises a quarter wavelength element coupled between the transmit/receive switch and the bandpass filter in each of the first and second branches for each diplexer.

[c23] 23. A system comprising a plurality of MIMO radio transceivers of claim 1, and further comprising a baseband signal processor coupled to the plurality of MIMO radio transceivers.

[c24] 24. The system of claim 23, wherein the baseband signal processor supplies the first and second baseband transmit signals to a first MIMO radio transceiver and supplies third and fourth baseband transmit signals to a second MIMO radio transceiver, and wherein the baseband signal processor processes the first and second baseband signals produced by the first MIMO radio transceiver and processes the third and fourth baseband signals produced by the second MIMO radio transceiver.

[c25] 25. The system of claim 24, wherein the receivers of the first and second MIMO radio transceivers simultaneously process receive signals detected at respective antennas coupled thereto to produce the first, second, third and fourth baseband signals, and wherein the transmitters of the first and second MIMO radio transceivers simultaneously process the first, second, third and fourth baseband transmit signals for simultaneous transmission of corresponding radio frequency signals by respective antennas coupled thereto.

[c26] 26. A method for radio communication comprising steps of:

a. coupling first and second radio frequency signals detected by first and second antennas to first and second receiver circuits on an integrated circuit;

b. downconverting the first and second radio signals from a common center frequency with the first and second receiver circuits to produce first and second baseband signals;

c. coupling first and second baseband transmit signals to first and second transmitter circuits, respectively, on the integrated circuit;

d. upconverting the first and second baseband transmit signals with the first and second transmitter circuits to produce first and second transmit radio frequency sig-

nals at a common center frequency; and

e. coupling the first and second transmit radio frequency signals to the first and second antennas, respectively, for simultaneous transmission.